Requirements for Recovering Fish Stocks

Joseph E. Powers
NMFS, Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149.
E-mail address: Joseph.Powers@noaa.gov.

Abstract.- Recently, requirements for recovering fish stocks were examined in the context of the Fisheries Conservation and Management Act of the United States. It was suggested that simple constant fishing mortality rate policies imposed difficulties because of uncertainties and variability in both management and biological processes; and that recovery plans for fishery resources that are depleted should include four necessary components: 1) a threshold measure (or measures) of the overfished state and periodic monitoring of the fishery resource relative to that measure; 2) a recovery period; 3) a recovery trajectory for the interim stock status relative to the overfished state; and 4) transition from a recovery strategy to an "optimal yield" strategy. A constant fishing mortality rate without an accepted recovery trajectory does not provide for "mid-course corrections" needed to adjust to differences between projected and realized resource status and in the risk choices of the managers relative to over-runs and under-runs of annual quotas. Recent changes in US fisheries policy suggest that additional constraints on recovery periods are being requested which addresses some of those difficulties. The implications of these policy changes relative to technical aspects of recovery plans are discussed.

Introduction

The Fisheries Conservation and Management Act (FCMA) of the United States and its amendments established domestic marine fisheries policy in relation to recovery processes for overfished stocks in the late 1980's. Through that legislation, requirements were developed for definitions of overfishing, i.e. definitions of the fishing rate, productivity and/or the stock level that presents a substantial risk of recruitment decline (Rosenberg, et al. 1994). The initial focus of these definitions was on the appropriateness of the criteria and the efficacy of measures relative to the criteria. However, the regulatory guidelines that establish the need for overfishing criteria also required that recovery plans be implemented for those stocks that are in an overfished state. Requirements for recovery plans under FCMA and problems that arose in implementation were presented (Powers 1996). Recent changes in United States marine fisheries legislation through the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) has provided further guidance to address recovery plans. The objective of this paper is to revisit recovery plan requirements (Powers 1996) in the context of the MSFCMA and to relate these to "control law" approaches (Restrepo and Rosenberg 1994) being considered for technical implementation.

Characteristics of a Recovery Plan

A recovery plan is a strategy of selecting fishing mortality rates or equivalent catches that will increase the status measure (e.g. biomass) above some minimum standard threshold within a specified period of time. Biological reference points relating to overfishing have been studied for many years (Gulland and Boerema 1973, Sissenwine and Shepherd 1987, Goodyear 1993) and have led to several fishery benchmarks used to guard against recruitment overfishing. The word *overfishing* implies an act of depletion; thus, is related to the fishing mortality rate. Additionally, there is the state of being *overfished* where the stock's status (e.g. biomass) is reduced below minimum standards. A recovery plan addresses both situations. However, the actions which might be imposed when the fishing mortality rate is exceeded will often differ depending upon the status of stock biomass. For example, a stock which is high in biomass and has little previous fishing history is not at as high a risk of recruitment collapse from a high fishing mortality rate as one with a low biomass that is below a biomass threshold. Hence, the actions to be taken for recovery depend heavily on the overfished status.

Four components were suggested as being necessary for a recovery plan (Powers 1996): 1) a threshold measure (or measures) of the overfished state and periodic monitoring of the fishery resource relative to that measure; 2) a recovery period; 3) a recovery trajectory for the interim stock status relative to the overfished state; and 4) transition from a recovery strategy to an "optimal yield" or target strategy.

The first of these (a threshold measure and monitoring of status) has its own uncertainties and scientific debate (Rosenberg et al 1993, Rosenberg et al 1994, Goodyear 1993, Mace and Sissenwine 1993) both in

The views expressed herein are those of the author, not necessarily NMFS' terms of the criteria to be used and the uncertainties commonly encountered in the estimation. With the new legislation (MSFCMA) it appears that the management debate about the criteria has been clarified [see Restrepo et al. 1998: maximum sustainable yield (MSY) is to be utilized as a limit threshold where fishing mortality rate at MSY (F_{MSY}) is not to be exceeded and spawning biomass is not to drop much below spawning biomass at MSY (B_{MSY})]. However, the other components of a recovery plan (recovery period, trajectory for recovery and transition to optimum) are often not addressed (Rosenberg et al. 1994). Therefore, the discussion in Powers (1996) is re-presented as a basis for examining effects of MSFCMA on their definition.

Recovery Period

The duration of recovery is the time until the status measure (e.g. spawning biomass) increases above the limit threshold. In several recovery plans of the southeast United States under FCMA, the duration of recovery has been based on a multiple (λ) of the lifespan (t) of the fish (king and Spanish mackerel, red snapper and other reef fishes). In those cases the recovery measure being utilized is the spawning potential ratio which is, in essence, a per-recruit measure. Therefore, once a constant reduced fishing mortality rate is applied for λt years, then (by definition) recovery is achieved. In practice the actual time to recovery depends upon year-class effects and regulatory implementation errors; nevertheless, the recovery periods in these cases were still defined in terms of the lifespan. The biological scientific input into this process was through the biological definition of the term "lifespan"; whereas, the fisheries management decision was in selecting the multiplier of the lifespan which was most appropriate for their management goals.

With MSFCMA, the threshold measure of an overfished status will be in units such as biomass or spawning stock levels. Thus, there is no direct argument for linking the duration of recovery period with lifespan, as suggested above for per-recruit measures. However, such a linkage is still useful because lifespan indicates the time in the future at which recruitment totally depends upon spawning from fish that have yet to be spawned as opposed to depending partially on those fish that already exist.

The recovery period should be long enough to allow an acceptable probability that the status measure(s) exceed the rebuilding target given the productivity of the stock. If the period is too short, recovery may not be feasible even with no fishing. If the period is too long, then biological advice becomes very uncertain due to uncertainties about future recruitment. Biological information on stock productivity should define whether a recovery period is infeasible (too short). Whether a recovery period is too long or not is more ambiguous to define biologically. Further research is needed to characterize the risk and uncertainty in recruitment projections. However, the proposed course of management action also will affect the recovery period. Delayed implementation might allow further stock deterioration and it would take longer for the stock to recover. If the recovery period is too long, then the achievement of other management goals may be delayed.

There should be stability and continuity to the recovery duration and, indeed, to the entire recovery plan. As new socioeconomic and biological/ecological information becomes available, there may be a need for flexibility to modify the duration of the recovery period to satisfy overall management goals. However, the process of modification should not be so flexible as to make the annual stock assessment advice offered to management ineffectual. Modifications should be subject to sufficient layers of review so that the changes are both significant and justified before they are implemented. Modifications should be responsive to realized recruitment and fishery changes during rebuilding and to credible scientific advice, rather than changes in short term non-biological objectives.

The MSFCMA has indeed provided guidance on the specification of a recovery period (Restrepo et al. 1998). The legislation has addressed the management role by providing overall constraints on the duration of the recovery period: limiting it to a minimum number of years (ten years) unless such a recovery is not biologically feasible. If it is not biologically feasible (the stock cannot recover within the minimum number of years with no fishing), then it is suggested that the recovery period revert to the minimum year constraint plus one generation time (see Restrepo et al. 1998).

Recovery Trajectory

An accepted recovery trajectory for each status measure should be a central theme for a recovery plan. Initiation of a recovery plan starts with a determination that the stock is overfished at a particular point in time. Then an end point is established which specifies the time at which we wish the status measure(s) to rise above the rebuilding target. However, there are infinite number of pathways by which the stock can get from the starting point to the end point. Without further guidance, there is no basis for scientific advice on management measures and monitoring of recovery. Any annual quota or fishing mortality rate would be biologically acceptable as long as there was a feasible route to recovery within the required time period (and with sufficient probability). However, effects such as dynamic recruitment patterns, quota overages and shifts in fishing strategies that arise subsequent to the implementation of the plan could lead to implementation errors (Rosenberg and Brault 1993) that could accumulate to the point that it is no longer feasible to reach the recovery target within the required timeframe. Mid-course corrections may be needed to bring recovery back on track or to allow fisheries utilization of “windfalls” brought about by events such as good recruitment or shifts in selectivity. Another strategy would be to utilize the “windfalls” to shorten the timed needed for recovery and then only use mid-course corrections when the resource falls below the planned trajectory. While biological constraints will limit the options, it is ultimately the manager’s responsibility for selecting among the feasible trajectories. Biological constraints will limit how quickly a stock will grow and the characteristics under which it will grow, even when there is no fishing. However, the benefits of conservation must be balanced against the social and economic costs in both the short and long terms.

As with the recovery period, new socioeconomic, biological or ecological information will require modifications to the recovery trajectory by management. However, modifications should be subject to sufficient layers of input and review so that the changes are both significant and justified, before they are implemented. The evaluation should be based on the expectation that the trajectory will or will not meet the recovery plan given the selected harvest rate strategy in the context of established socioeconomic objectives for the fishery.

Transition from Recovery to Target Objectives

Under MFCMA, recovery plans were to move from recovery towards optimal yield, i.e. toward the targeted management objectives. During the recovery period the goal was to bring the status measure(s) above the rebuilding target. Once recovery was complete then the management target should promote optimum yield. What was undesirable is for the overfished and overfishing thresholds and the optimum target to be identical after recovery has been achieved. If that were to be the case, then even in the best of circumstances the status measure would decline to the threshold and then randomly deviate about the threshold. Stock assessments would classify the stock as overfished every time the deviation was below. This, of course, would cause enormous difficulties for management to implement or dismantle recovery plans whenever there was a small deviation between the status measure and the management target. A primary objective of fisheries management should be to avoid the overfished status.

An example of a transition to an optimum might be one in which there is a transition from recovery fishing mortality rate which is half of the rate to be used to obtain optimum. When the status measure(s) recover to levels above the threshold, then fishing mortality rate can be increased to that which would produce the optimum, as defined by the managers. The important thing is that the “optimum” not be defined to maintain a stock at the overfished threshold (Rosenberg et al. 1994). This cannot be deemed optimum in a biological sense.

The role of the scientists in this process is to determine whether the optimum fishing mortality rate defined by management will put the stock at risk of being overfished, i.e. to determine the likelihood that a particular harvest rate or stock size could put the stock at risk of being overfished. In that case an optimum based on that particular rate or stock size would not be acceptable. Given that a stock has recovered and that an acceptable fishing mortality rate is selected, scientific advice should offer acceptable catch levels to realize that rate and an interim probability of the state of the resource relative to the overfished state. The transition to optimum should be selected from feasible options by the fisheries managers. For severely depleted stocks, transition plans to optimum are not high priority as compared to determining the threshold measure, the recovery period and the recovery trajectory. If the recovery period is lengthy, then the inevitable debates associated with defining optimum are not as important as the initiation of recovery. As recovery approaches the threshold, then debates over what form optimum yield should take and how quickly it should be achieved rise in priority.

Relationship of Recovery Plans with Control Rules

The above argument has stressed the importance of the four components of a recovery plan: threshold criteria, recovery period, recovery trajectory and transition to a target. However, the dominant school of scientific thought has argued in terms of control rules, i.e. specific advice relating fishing mortality rates with current biomass (Rosenberg et al. 1994, Restrepo and Rosenberg 1994, Restrepo et al. 1998). In fact, the two approaches are equivalent. Defining a control rule is essentially the process of determining an appropriate trajectory, recovery period, target and threshold. This is demonstrated by the following simple example using a population described by logistic dynamics ($r=0.3$, $K=1$) and an initial biomass of 20% of carrying capacity.

First examine the linear control rule in the solid line of the lower panel in Figure 1. This control rule generates specific biomass and yield trajectories (solid lines in upper panel of Figure 1). An alternative control rule (dashed lines in Figure 1) generates different trajectories. A manager would look at the trajectories and quickly note that the dashed alternative has less impact on yield initially with a slower recovery rate than the solid line trajectories.

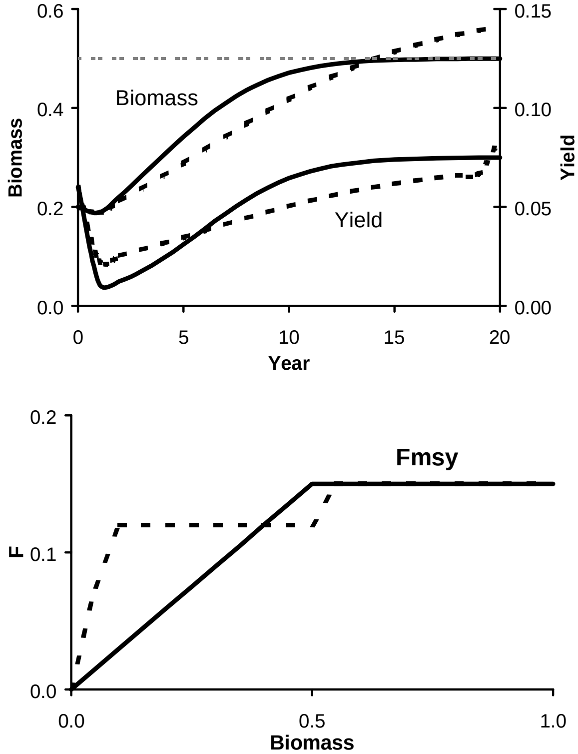

Figure 1. Biomass and yield trajectories (upper panel) given control rules (lower panel); the solid line control rule in the lower panel corresponds to the solid line trajectories in the upper panel; the dashed lines also correspond.

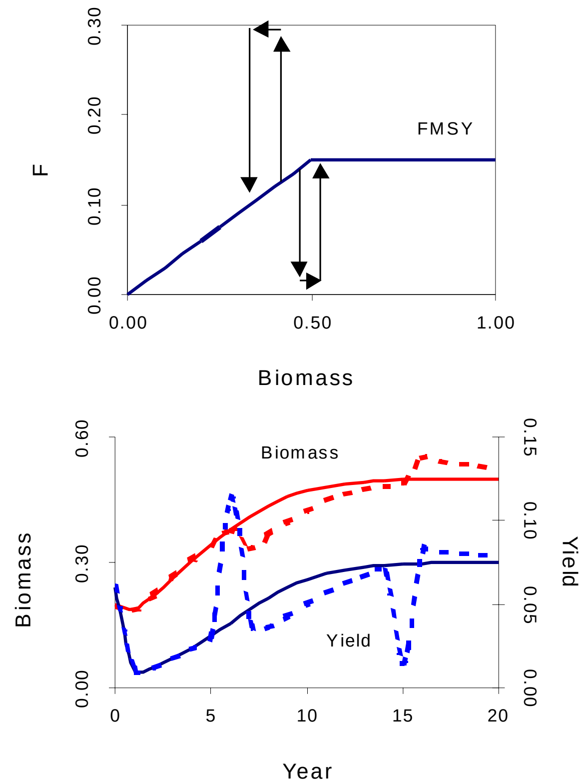

Figure 2. Control rule (upper panel). The arrows in the upper panel indicate the adjustment when actual F is too high and again when it is too low. The bottom panel gives the corresponding biomass and yield trajectories (dashed lines) compared to the perfectly implemented control rule (solid lines).

The crux of defining a control rule (especially in the ascending limb) is to determine the short term and long term management constraints in recovery: can large reductions in yield be implemented quickly? Is this technologically and politically feasible? These are the questions that must be addressed in developing the recovery plan. Therefore, it is my opinion that these issues are best discussed and communicated with managers in the context of recovery trajectories and recovery periods, rather than as control rules. At the scientific level one can easily transform control rules to recovery trajectories and *vice versa*.

Also, a control rule (for example as in Figure 2) implies that an adjustment is to be made in fishing mortality rate when implementation has not been perfect. If fishing mortality rate is too high or too low than the recommended F in the next year is adjusted, based upon perceived biomass. An example of this is shown (using the same logistic dynamics) assuming that fishing mortality was mis-implemented twice during a recovery period, once where it was too high and once where it was too low. The adjustments that are made (using the control rule) are depicted by the arrows in the upper panel of Figure 2. The resulting dynamics in the biomass and yield trajectories are shown in the dashed lines in the lower panel. These are compared to the trajectories with a perfectly-implemented control rule (solid lines). When fishing mortality rate is too high, yield increases and biomass decreases.

Under the control rule in the example, compensation in the fishing mortality rate is done linearly based upon stock dynamics in the intervening period. Another adjustment procedure might be to return the biomass trajectory back to the original (perfectly implemented) alternative (Powers 1996). In this case this implies a particular F control rule, as well. But again, I argue that this is best discussed in a management context using biomass and yield trajectories, rather than as control rules, *per se*. The control rule approach is certainly appropriate in defining feedback mechanisms, but these rules should be couched in terms of biological and management quantities, as well.

Summary Comments

A constant fishing mortality rate policy based on standard fisheries benchmarks such as $F_{30\%\ SPR}$, F_{MSY} or $F_{0.1}$ theoretically should be adequate for a recovery plan even when there are stochastic fluctuations. However, experience shows that implementation of a constant F policy may be imperfect and the variations in F can be non-random around the target. There may be a series of risk-prone decisions which lead to cumulative deleterious effects on the fish stock or there may be year class effects that accumulate over several years. These are especially troublesome with recovering stocks in that there may be political and economic pressures to harvest the surplus which has accumulated from previous regulations which would allow the stock to grow toward recovery. Thus, the recovery rate may slow or stop completely. Rosenberg et al. (1994) and Restrepo and Rosenberg (1994) addressed this issue in the context of "control laws", i.e. rules that specify F levels depending upon where the stock is relative to its overfishing and overfished thresholds. This paper repeats the Powers (1996) argument that the control law should be translated into an acceptable trajectory of the metric used to define the overfished level and that the target F level should be the F that will keep the trajectory on track. If the fishing mortality rate is the one that keeps the stock on its recovery trajectory, then progress toward recovery can be evaluated directly, as well as short term gains or losses of risk-averse or risk-prone decisions. This allows the development of a long term strategy. This approach also makes the management objectives clear so that scientific advise can be more direct.

The MSFCMA has provided some guidance in terms of defining threshold and target criteria, recovery periods and transition to targets. It also spawned discussion which has stressed the importance of interim milestones for evaluating recovery which is, in effect, the beginning of discussions on appropriate trajectories. However, there is still a need to develop further criteria for recovering trajectories. In particular, what sort of actions ought be taken when stock sizes are very low. When a recovery plan is implemented, there should be a low probability of further deterioration and a high probability of short term improvement. But, there is no consensus on what appropriate definitions of "low" and "high" ought to be. There is a need for scientific work (presumably by simulation studies) to guide this choice.

Literature Cited

Goodyear, C.P. 1980. Compensation in fish populations. p. 253-280. *In* C.H.Hocutt and J. R. Stauffer, Jr. (ed.) Biological monitoring of fish. Lexington Books, D. C. Heath and Company, Lexington, Mass.

Goodyear, C.P. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use. p. 67-81.*In* S.J. Smith, J.J. Hunt and D. Rivard (ed.) Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Gulland, J.A. and L.K. Boerema. 1973. Scientific advice on catch levels. Fishery Bulletin 71:325-335.

Mace, P.M. and M.P. Sissenwine. 1993. Risk evaluation and biological reference points for fisheries management. p. 101-118. *In* S.J. Smith, J.J. Hunt and D. Rivard (ed.) Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Powers, J.E. 1996. Benchmark requirements for recovering fish stocks. North American Journal of Fisheries Management 16:495-504.

Powers, J.E. and V.R. Restrepo. 1992. Additional options for age-sequenced analysis. International Convention for the Conservation of Atlantic Tunas Collective Volume of Scientific Papers 35:355-361.

Powers, J.E. and V.R. Restrepo. 1993. Evaluation of stock assessment research for Gulf of Mexico king mackerel: benefits and costs to management. North American Journal of Fisheries Management 13:15-26.

Restrepo, V.R., and A.A. Rosenberg. 1994. Evaluating the performance of harvest control laws under uncertainty via simulation. Int. Council Explor. Sea, Longterm Management Measures Working Group, WD 18. Miami, Florida, USA.

Restrepo, V.R. , G.G. Thompson, P.M. Mace, W.L. Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade and J.F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. National Marine Fisheries Service, NOAA Technical Memorandum, NMFS-F/SPO-31.

Rosenberg, A. and S. Brault. 1993. Choosing a management strategy for stock rebuilding when control is uncertain. p. 243-249. *In* S.J. Smith, J.J. Hunt and D. Rivard (ed.) Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Rosenberg, A., S. Swartz and G. Darcy. 1993. The scientific basis for definitions of overfishing in the United States p. 6-18 in A.A. Rosenberg [ed.] Report of the Second Annual National Stock Assessment Workshop. NOAA Tech. Memo. NMFS-F/SPO-8.

Rosenberg, A., P. Mace, G. Thompson, G. Darcy, W. Clark, J. Collie, W. Gabriel, A. MacCall, R. Methot, J. Powers, V. Restrepo, T. Wainwright, L. Botsford, J. Hoenig and K. Stokes. 1994. Scientific review of definitions of overfishing in U.S. fishery management plans. National Marine Fisheries Service. Washington, DC. 205p.

Sissenwine, M.P. and J.G. Shepherd. 1987. An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aqua. Sc. 44:913-918.